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1. Chassis Description

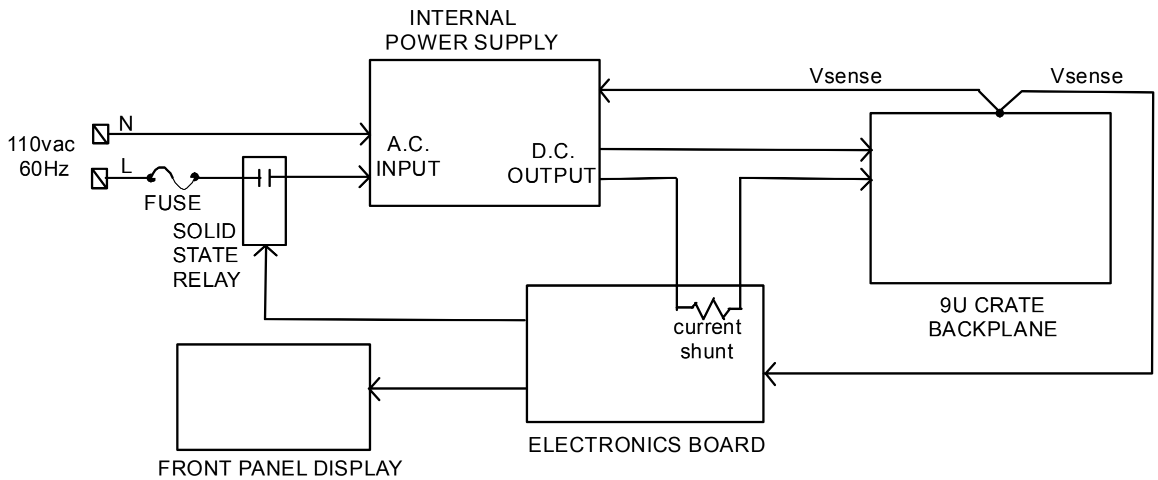
The CDMS Power Supply, version 2, is designed to power the CDMS 10U crates, housing either Zip or RTF Modules. It can also be used to power a CDMS Zip version 1, 9Ucrates, however an external adapter board is necessary for the sense connector. This required adapter board is available from the Fermilab CDMS group.

The chassis contains seven individual power supplies, four 15 Volt/15Amp supplies, one 5V/1A supply, one 5V/18A supply and one triple output supply of +/-15V, .4A and +5V, 2A. The supplies are arranged in the following configurations and used for the listed purpose:

- +/- 15V, Front End Electronics (FE) (two 15V/15A supplies).
- +/- 15V, Analog Electronics (two 15V/15A supplies).
- +5V, Heater (5V/1A supply)
- +5V, Digital Electronics (5V/18A supply)
- Triple output supply for chassis electronics (+/-15V, .4A and +5V, 2A)

Each of the seven power supplies have their AC input individually fused, per the manufacturer's specifications. All fuses are accessible on the rear panel, and all except the main chassis fuse have neon light indicators which light when a fuse is blown. Fuse types are listed in the specifications section. The output voltages are regulated locally via resistors between the voltage output terminals and the sense terminals or remotely at the Crate Backplane. Two separate pairs of sense leads are used for each of the individual power supplies and these leads are brought from the backplane, back to the chassis through J3. One pair of sense leads goes to the sense terminals of the power supply for voltage regulation; the other pair going to the electronics board for voltage monitoring.

2. Single Power Supply Block Diagram (six per chassis)



3. Operation

Turning the AC POWER "ON" at the front panel, turns on the internal power supplies in a user defined, programmable sequence. The two 15 volt power supplies that make up the +/- 15V FE voltages, are hard wired to always turn on in pairs. The same is true for the two 15 volt power supplies that make up the +/- 15V Analog voltages. The preset sequence energizes the FE supplies first then the Analog supplies followed by the Digital supply and then the Heater supply. Because of the 1 Hz clock, the sequence advances at one-second intervals, until the sequence is complete. To change the speed of the sequence, one must change the frequency of U 27, on schematic 4-1(refer to the Logic Section Schematic of this manual). The position in the sequence that a particular power supply turns on, is determined by a nine-position-switch that each supply has, which selects where in the sequence it will turn on. These switches are located on POWER SUPPLY MONITOR DISPLAY BOARD located immediately behind the front panel.. If any of the power supplies fails to turn on and reach the proper voltage before the next power supply in the sequence is turned on, the electronics will stop the sequence and shut off all of the power suppies except the "Triple output supply for chassis electronics (+/-15V, .4A and +5V, 2A)", which is used only to operate the Power Supply chassis. Cycling the AC POWER switch will reset the chassis. It is recommended to wait 5 seconds before a restart. This is because a lightly loaded power supply will retain voltage on it`s output filter capacitors for a few seconds. The chassis electronics will interpret this as a voltage present when it should not be and prevent the start up sequence.

The POWER SUPPLY MONITOR DISPLAY BOARD located directly behind the front panel, has twelve 10-segment LED Display devices mounted on it, which protrude through the front panel. Six are used for monitoring the six power supply voltages, and six are used for monitoring the power supply currents. The Triple output supply for chassis electronics, is not monitored. What is monitored is the voltage level at the crate backplane and the current drawn by the crate from each power supply. Voltage monitor jacks on the front panel allow the user to make a more precise measurement of the crate voltages with a DVM. The DVM should have an input impedance > than 10 Kohm. The power supply front panel selector switch, selects which voltage is available at the front panel jacks.

4. Remote Reset and Status Monitoring

The chassis can be reset and restarted remotely, by applying a momentary (greater than 1 millisecond) voltage between 3 and 50 volts to pin A with respect to pin B of J4. A negative voltage on pin A with respect to pin B should not exceed 5 volts. Both pins, A and B, are floating with respect to all other parts of the power supply chassis, by being connected to an opto-isolator. J4 is an 8 pin, cylindrical connector located in the lower right hand (viewed from the rear) portion of the rear panel. The power supply will remain in the reset mode as long as the voltage is present.

The status, i.e., are the six supplies up and running at the proper voltages or are they off, can be monitored through J4 as well. Pins C, D, E and F are used for this purpose, and like pins A and B, all four pins are isolated from the rest of the power supply chassis. This means that an external voltage needs to be supplied to operate this output. Pins D and F, are tied together internal to the power supply. Putting a positive voltage, between 3 and 7 volts on pin C with respect to pins D and F. Pin E should be tied through a 2.2k ohm resistor, to the same voltage as pin C. The result being that a low voltage on E means the power supply is up and running properly, whereas a voltage near the value applied to pin C, indicates there is a problem.

5. Chassis Electronics

The chassis electronics board performs three functions:

A. Turning on the internal power supplies in a user defined, programmable sequence.
B. Monitoring the crate backplane voltages for an undervoltage or overvoltage condition. If any one or more of the six voltages is more than +/- 6% away from the nominal setting, all six of the power supplies will be shut off.
C. Displaying the crate voltages and current draws on the power supply chassis front panel.

A. Programmable Sequence: See drawing 4-1 Logic Control Section.

Turning the AC power switch on or generating a remote reset starts “1 Hz Clock”, (U27) via U25. U27 generates pulses of ~1Hz which are sent to an 8-bit serial in / parallel out shift register (U28). The shift register starts out with all outputs at a low voltage (logic “0”). The first clock pulse causes pin 3 to go high. The second clock pulse causes pin 4 to go high and pin 3 to remain high. The third clock pulse causes pin 5 to go high with pins 3 and 4 remaining high, and so on. When the last bit (Q7 or pin 13) of the shift register goes high, the 1 Hz Clock (U27) is stopped by a low logic level on it’s reset pin. The first 7 bits of the shift register go to positions 1-7 on four rotary switches (SW2 – SW5). Each of these four switches correspond to one of the four internal power suppy types (Heater, Front end, Analog and Digital) as labeled on the board. Setting a power supply type switch to a position from 1 to 7 determines where in the sequence, that power supply type will be turned on. To turn a particular power supply type on, the selected high bit from the shift register output, U28 is routed through the selector switch to driver U2, which drives a solid state relay, turning it on and thereby supplying AC power to the selected power supply type.

Each of the four switches (SW2 – SW5), has a companion switch mounted directly below it on the board (SW6 – SW9 respectively). Each of these switches has six of their poles connected to one of six window voltage comparators. The function of any given window comparator is to determine if the input voltage to the window comparator is inside or outside a predetermined window of voltage. In this power supply unit, each of the six power supply voltages used to supply power to the Crate has a window comparator on it. The window is set at +/- 6% of the nominal voltage. If the voltage is within 6% of the nominal voltage, the comparator puts out a high logic level, indicating the voltage is okay, otherwise the logic level is low. The function of these switches then, is to bring the outputs of the window comparators back to the digital comparator (U34) which compares the output of the window comparators with the output of the shift register. If a power supply was turned on by a high level out of the shift register, and the window comparator indicates that the power supply is within 6% of its nominal voltage, by providing a logic high at it’s output, then the digital comparator will indicate that those two inputs are equal, allowing the sequence to continue. In the case of the Frontend and Analog voltages which are dual supplies, both supplies are turned on together and their window comparator outputs are wire OR’d so that only four switches are required to turn the supplies on and only four more switches to read back the output of the window comparators. The output of a window comparator goes to the common terminal on the switch, with the various pole positions being connected to the inputs to the digital comparator. The companion switches **must be set to the same position for proper operation.** Switch positions 8,9, and 0 on all switches have test functions and **should never be selected in the normal operational mode** because the window comparators function will be lost. In these three positions, the output of the shift register is sent to both inputs of the digital comparator guaranteeing that the comparator will always indicate that the two inputs are equal. For example selecting position 8 of switches 2, 3, 4 or 5 causes the Digital, Analog, Front End or Heater respectively, to be turned on continuously. Position 9 is just the opposite,i.e., these power supplies are turned off continuously.

B. Monitoring: See Monitor Board Schematic List; sections 8(Voltage Monitor Schematics) & 9(Window Comparator Schematics)

The crate sense voltages are brought onto the electronics board via connector J1, pins 13 through 24 inclusive(see drawing 2-3). These six pairs of signals are then sent to the appropriate Voltage monitor circuitry (see Voltage Monitor Schematics; Drawings 8-1 through 8-6). The voltage monitor circuits scale and shift the read back voltage appropriately to drive the front panel voltage displays and the 6% window comparators. If any voltage is out of spec (+/- 6%) it`s window comparator will output a low (0V) to the logic section which will shut off all the power supplies.

Current output is monitored via board mounted shunt resistors and current monitor circuitry which scales the current-shunt voltage appropriately for driving front panel LED display. There is no overcurrent trip.

C. Display: See Monitor Board Schematic List; sections 6(Current Display Schematics) & 7(Voltage Display schematics).

This portion of the board uses 10 segment LED bar graphs to provide a visual representation of the current output of each power supply and the voltage (measured at the back plane) of the electronics crate. There are also test points on the power supply front panel that can be used to measure the output voltage of each supply using an external meter with an input impedance > than 10 Kohm. The front panel voltage displays are calibrated so that the center LED equals the nominal output voltage of the supply, and has a range of + /- 6% around that value.

Two adjacent LEDs may be lit when the display is at the transition between them. This feature is built in by the manufacturer to prevent the possibility of no LED being lit at the exact transition point.

D. Test Features:

The board has several test features to aid in troubleshooting the board and the chassis.

1. <u>12 position dual header J2:</u> To bench test a chassis without a crate connected, alternate sense voltages must be supplied to the board voltage window comparators circuits so that they don't shut the power supply down. This can be accomplished by removing the 12 position shunt, stored on the Monitor Board connector J5, and placing it on J2 (See schematic 2-3) (labeled **test position** on the Monitor Board). This action connects the five of the individual power supply sense terminals to the voltage monitor circuits. The Heater supply does not have sense terminals so the output terminals of this power supply are connected to it's window comparator instead. <u>This 12 position shunt must be removed from header J2, and returned for storage, to J5 before powering a crate, or the power supply electronics will be monitoring the supply outputs rather than the crate</u>. The <u>12 position dual header J5</u> (labeled **run position** on the board) is provided for storing the shunt and is not electrically connected to anything on the board.
2. <u>Reset switch SW1:</u> Pushing SW1 on the Monitor Board resets the Monitor Board and initiates the start up sequence.
3. <u>LED`s LS1-LS6 & LW1-LW6:</u> LS1-LS6 (yellow LED`s) indicate the last latched state of the shift register U28. These are the turn on commands to the power supplies. Thus if a power supply has it`s sequence switch set to 3 it will receive the turn on command when LS3 lights. LW1-LW6 (green LED`s) are connected to the outputs of the window comparators which monitor the crate voltages, and indicate the last latched state of the window comparator outputs. Thus if a power supply is set to switch position 3 and is operating within the voltage window, LW3 will light. Because these LEDs indicate the last "latched state", even if the power supply stops the sequence or shuts down, one can look at the LEDs and see how far the sequence got before it quit or shut down. This feature simplifies trouble shooting the Power Supply logic. Switch pairs for each power supply type(as marked on the board) must be set in the same position to operate correctly.

4. Special Switch Positions: Position 8 of switches SW2-SW5 will send a logical high, (constant 5V; "on" command) to the corresponding power supply regardless of the control logic condition. Position 9 of any of the switches, SW2-SW5 provides a logical low (constant ground; "off" command) to the corresponding power supply regardless of the control logic condition. In any case, always set the companion switches SW6-SW9 match switches SW2-SW5. This removes the window comparator feedback for that power supply from the Equality Comparator (U34). That input will then be connected (via a 10k resistor) to the level of the adjacent input coming from the shift register (U28) preventing the logic from shutting down the chassis. These special switch positions should never be used for powering a crate with modules plugged into it, because the crate protection is defeated.
5. Voltage Test Points: Test points TP1-TP6 are available to measure the precision reference voltages required to operate the window comparators and the display circuits, that are used on the Monitor Board. These test points are provided for easing troubleshooting.

6. Board Theory of Operation: Refer to Power Supply Ver. 2 Monitor Board schematics.

A. **Current Section:** Current output of the internal power supplies is measured via Monitor Board mounted, current shunt resistors and displayed on the power supply chassis, front panel, 10 segment LED displays.

1.Current Monitor: Schematic 5-5 is a typical current monitor circuit. Power supply current is run through the current shunt R3 developing a small voltage of 5mV per ampere. In order to maintain a zero volt difference at the input of op-amp U50, the op-amp forces enough current through R100 (via the FET T4) to produce an equal opposing voltage to that across R3. This current through R100 flows through the 2K resistor R12 producing a scaled up voltage (20 X) for the next stage(U13) which has a gain of 1, providing a final output sensitivity of 100 mV per ampere.

Example: A 10 amp current through R3 develops a voltage drop of 50 mV. U50 drives T4 enough to develop 50mV across R100. A current of 0.5 mA (50mV \ 100 ohms) flows through R100, T4, and R12. This develops 1V across R12 (0.5mA * 2K ohms). Thus the scale factor is 1V = 10A.

This voltage is input to a difference amplifier U13 which has an internal gain of 0.1 and an external gain of 10 for a net gain of 1. The output is referenced to board ground and sent to the current display driver (schematic 6-5).

2. Current Display: Schematic 6-5 is a typical current display circuit. The LM3914N Dot/Bar Display Driver senses analog voltages and drives 10 LEDs providing a linear analog display. A high reference of 1.5V and the low reference at ground yields a scale factor of .15V per segment. Since the signal in from the Current Monitor is scaled at 1V\10A then one segment on the display (.15V) equals 1.5 amps and full scale equals 15 amps from the power supply.

B. **Voltage Section:** The power supply output voltages are measured at the backplane of the CDMS 10U crates. These voltages are processed by the voltage monitor circuits and then sent to the front panel displays and to the window comparators. The window comparators determine if the voltage levels are within specification(**+/- 6%),** and send the decision to the logic section.

1. Voltage Monitor: Schematic 8-5 is a typical voltage monitor circuit. The crate voltage goes to a difference amplifier U22 that has a single-ended output referenced to board ground. The overall gain is 1.0 so a 1% change on the 15V output results in a 150 mV change in the output of this circuit. R 131 is connected to a reference voltage to create an offset so that 15 volts out of the power supply provides an output out at the voltage monitor output of 1.5 volts, rather than 15 volts. The display driver, which receives this voltage, is set to turn on the 5th segment when the voltage is 1.35 to 1.5 volts and turn on the 6th segment from 1.5 volts up to 1.65 volts. Each 150mV up or down, turns on the next LED up or down respectively.
2. 2. Voltage Display: Schematic 7-5 is a typical voltage display circuit. Operation is similar to the current display except that the high reference is 2.1V and the low

reference is 0.6V. This provides 10 LEDs over a 1.5 volt spread or 150 millivolts per LED. That makes each LED 1% of the nominal output voltage. The first LED turns on between 0.75 and 0.9 volts, the second from 0.9 to 1.05, third 1.05 to 1.2. fourth 1.2 to 1.35, fifth 1.35 to 1.5, and so on to the tenth from 2.1 up. The display is scaled to read a maximum voltage error of 5%. The top LED means the voltage is 4 to 5% high and the bottom LED is 4 to 5% low (see front panel graphics).

3. Window Comparators: Schematic 9-5 is a typical window comparator circuit. The window comparators determine if a power supply is within the +/-6% tolerance allowed. If it is, the comparator outputs a high level (+5V) to the logic section. If the comparator input goes above the high reference or below the low reference the comparator outputs a low (0V) to the logic section causing the chassis to shut down.

C. Logic Section: Schematics 4-1 and 4-2 are the logic section. This section use TTL level logic to turn on the power supplies in a sequence and shut the power supplies off if any voltage is out of spec.

1. Reset: Applying a voltage of +3 to +50 V (remote reset) to the pin 2 (with respect to pin 3) of U3 longer than 1 millisecond in duration, or pressing SW1 (manual reset) puts a low on pin 1 of U16. U16 then sends a low to several AND gates of U25. U25 pin 3 resets the 1 Hz Clock (U27), pin 8 resets the shift register U28, and pin 11 gets inverted and ANDed with the clock output to initially have U33 and U35 take a sample of the Shift Register output, as well as the Window comparator outputs. Immediately following reset, all those outputs should be low; i.e., all LEDs off.
2. Startup Sequence: Turning on the power supply chassis AC switch or releasing the reset sends a high to pin 4 of the clock (U27) which starts generating pulses at 1 Hz. U28 is an 8-bit serial-in/parallel-out shift register with it`s inputs tied to Vcc. Thus each each pulse of the clock shifts a one into the output registers. The 8-bit bus S{1,8} on the output ties the first 7 bits tied to positions 1-7 on the selector switches SW2 - SW5. The position of each switch corresponds to which pulse count will turn that power supply on. Switch positions 8,9, & 0 are not available to use. The 8th bit is fed back to the clock reset pin to shut off the clock after the eighth count.
3. Logic Comparator: Each of the 4 switches has companion switch mounted directly below it on the board (SW6-SW9). These switches receive a high or low level from window comparators that monitor the power supply voltages (at the crate backplane). A high level indicates the voltage is in range and a low level indicates it is out of range. Setting these switches to positions 1-7 put these bits on the 8-bit bus W{1,8}. An 8-bit Magnitude Detector (Equality Detector), U34, compares bus S{1,8} to bus W{1,8} to see if the power supply turn on commands match the expected results. Each pair of selector switches must set to the same position for proper operation. Eight 10K pull up resistors connect the respective lines of the 2 busses. This is done so that any line on the W{1,8} bus not connected to a window comparator will float to the level of the respective S{1,8} line in order to satisfy the Equality Detector, U34. When there is equality between the 2 busses, U34 outputs a low from pin 19 and when there is inequality, pin 19 is high. This is the key action for shutting down the chassis when a crate voltage is out of acceptable range.
4. Latches: Since there is a lag time between on commands from the shift register (U28) and the feedback from the window comparators, the output of the equality detector (U34) will sometimes momentarily go high during a normal startup sequence. For this reason the output of U34 goes to a D-type latch (U33 pin 3) that receives it's latch enable (pin 11) from the same clock pulse that increments U28. However, the clock input to U28 gets inverted, so whenever U28 is being incremented, U33's latch is disabled and the momentary high at U34's output does not get latched through U33. This latch output (U33 pin 2), which is low when operation is normal, is fed back through an inverter to the latch enable (pin 11). This allows continuous latching of U34's output once the clock has stopped running.

U33 also has 6 D-type inputs connected to the first 6 data lines of bus S{1,8}. The outputs are connected to 6 yellow LEDs. U34 does the same for the first 6 data lines of the W{1,8}bus. The outputs are connected to 6 green LEDs. The LEDs light when their line is high and give a visual representation of the shift register (U28) output and the window comparator readbacks.

5. Chassis Shutdown: If a crate voltage gets too high or low, it's respective window comparator sends a low to U34 causing it's output to go high. This high is passed through U33 to pin 9 of inverter U26. The low from U26 pin 8 passes through an AND gate (U25) to the reset (pin 9) of the shift register (U28) clearing it's outputs which shuts down all the power supplies.
6. Inverting Buffer: The outputs of the shift register (U28) go to an inverting buffer (U2). The power supplies are turned on by solid state relays mounted inside the chassis. The relays are activated by a DC voltage on their input terminals. The + input terminals are tied to +5 volts and the – terminals are connected to the outputs of U2. A high on a U2 input causes a low output providing a ground for the +5 volts on the relays input terminals.
7. Remote Status:

7. Specifications:

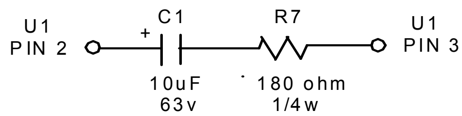
A. Fuses:

	Type	Rating	Power Supply
F1	3AG	15A	main chassis fuse
F2	3AG	6A	+15V Front End
F3	3AG	6A	-15V Front End
F4	3AG	.8A	Chassis Electronics
F5	3AG	.125A slow blow	+5V Heater
F6	3AG	6A	+15V Analog
F7	3AG	6A	-15V Analog
F8	3AG	2.5A	+5V digital

B. DC Output Pinout:

Connector Pin	Power Supply	Terminal	
J1-A	+15V Analog	(+)	
J1-B	+15V Analog	(-)	to crate analog ground plane
J1-C	-15V Analog	(-)	
J1-D	-15V Analog	(+)	to crate analog ground plane
J1-E	+5V Digital	(+)	
J1-F	+5V Digital	(-)	
J2-A	+15V Front End	(+)	
J2-B	+15V Front End	(-)	to crate front end ground plane
J2-C	-15V Front End	(-)	
J2-D	-15V Front End	(+)	to crate front end ground plane
J3-E	+5V Heater	(+)	
J2-F	+5V Heater	(-)	

8. Condor 15 Volt Power Supply Modification: When powering up a pair of the 15 volt Condor power supplies that are hooked in series (+ & -15V) a common mode latch up condition can occur. An RC network is added to the negative 15 volt power supply to slow it's response time and prevent the latch up. A 180 ohm, ¼ watt resistor and a 10 uF, 63V capacitor are placed in series between pin 2 and pin 3 of U1 on the power supply circuit board. The + side of the capacitor goes to pin2. Places for these components are available on the board as C1 and R7. A power supply modified as such can still be used for the positive 15 volt supply by cutting and lifting one end of the resistor.


U1
PIN 2
C1
+
10uF
63v
R7
180 ohm
1/4w
U1
PIN 3